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A SCIENTIFIC EVALUATION OF TWO HABITAT IMPROVEMENT PROJECTS FOR ATLANTIC SALMON (*SALMO SALAR*) CONDUCTED WITHIN THE GANDER RIVER WATERSHED, NEWFOUNDLAND, CANADA.

K. D. Clarke, D. A. Scruton, C. J. Pennell and D. Coté

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A Scientific Evaluation of Two Habitat Improvement Projects for Atlantic salmon (*Salmo salar*) Conducted Within the Gander River Watershed, Newfoundland, Canada.

by

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Habitat improvement and restoration initiatives have formed a significant component of efforts to revitalize Atlantic salmon stocks throughout Newfoundland, Canada. These habitat projects have taken many forms but several have aimed at removing natural barriers to migrating anadromous Atlantic salmon, thus opening new habitats for freshwater rearing and production. Most of these habitat improvement initiatives have relied on the natural straying of individuals to colonize the new habitat yet very little evaluation of this methodology has been conducted. This report provides an overview of an evaluation of two such projects conducted within the Gander River watershed under the auspices of the Canadian Newfoundland Agreement for Salmonid Enhancement and Conservation. Although limited in their scope, these evaluations have not shown any evidence of colonization within the new habitats in the short term. A discussion of the pros and cons of the methodology is presented with recommendations for future projects that may want to open new habitats to increase the production of a target species.

Résumé

Clarke, K. D., D. A. Scruton, C. J. Pennell, and D. Coté. 2001. A Scientific Evaluation of Two Habitat Improvement Projects for Atlantic salmon (*Salmo salar*) Conducted Within the Gander River Watershed, Newfoundland, Canada. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 2575: iv + 16 p.

Les initiatives d'amélioration et de restauration de l'habitat ont représenté une part importante des efforts déployés pour revitaliser les stocks de saumon de l'Atlantique dans l'ensemble de la province de Terre-Neuve, au Canada. Ces initiatives ont pris de nombreuses formes, mais plusieurs visaient à éliminer les obstacles naturels à la migration des saumons de l'Atlantique anadromes, pour ouvrir de nouveaux habitats à la production et à la croissance en eau douce. La plupart de ces améliorations de l'habitat reposaient sur la colonisation du nouvel habitat par la souche naturelle de saumons, mais cette méthodologie a été très peu évaluée. Le présent rapport donne un aperçu d'une évaluation de deux initiatives prises dans le bassin hydrographique de la rivière Gander, dans le cadre de l'Entente Canada - Terre-Neuve de mise en valeur et de conservation des salmonidés. Quoique de portée limitée, ces évaluations n'ont pas fourni la preuve d'une colonisation des nouveaux habitats à court terme. On discute ici des avantages et des inconvénients de la méthodologie et on formule des recommandations sur les initiatives futures visant à ouvrir de nouveaux habitats pour accroître la production d'une espèce donnée.

1.0 Preface

The decline in salmonid stocks in Newfoundland and Labrador, coupled with increasing demands on salmonid resources, has focused attention on maintaining and restoring salmonid habitat. As a result of the increased emphasis on fish habitat, a number of major habitat improvement and restoration programs have been undertaken in Newfoundland and Labrador in the past decade. Programs have included two major 5-year federal-provincial agreements; the Newfoundland Inshore Fisheries Development Agreement (NIFDA) - Small Stream Component (1988 to 1992) followed by the Cooperation Agreement for Salmonid Enhancement and Conservation (CASEC) - Habitat Improvement and Restoration Component (1992 to 1997). A number of other programs have supported regional habitat restoration initiatives, including the Environmental Partner's Fund (EPF) of Environment Canada, Canada's Green Plan - Habitat Action Plan (HAP), Wildlife Habitat Canada, the Newfoundland Conservation Corps 'Green Teams', and others.

The habitat projects conducted under these agreements tended to be small community driven initiatives with an overall low technical complexity. The methodologies employed were generally those developed and used for salmonid habitat enhancement in other jurisdictions and very little evaluation of the results was conducted in a scientific framework (Scruton et al. 1997). The few projects that were evaluated tended to be the more complex restoration initiatives or those undertaken specifically for research purposes (Bourgeois et al. 1993; Mitchell et al. 1998; Scruton et al. 1997; 1998; Van Zyll de Jong et al. 1997). One of the more popular improvement methodologies that required very little scientific expertise was the removal of migration barriers. These projects generally aimed to open new habitats for anadromous Atlantic salmon (*Salmo salar*), with the expectation that this habitat alteration would increase the productive capacity of the watershed for this species. This type of project has generally relied on straying within the existing population to colonize the new habitats and few, if any, have been scientifically evaluated.

2.0 Introduction

Habitat improvement, in the context of this report, refers to changes made in a natural ecosystem to improve the productive capacity of the entire ecosystem to the benefit of a target species and/or community. The populations most often targeted in Newfoundland are those of anadromous and resident salmonids. The most abundant and widespread of these are the Atlantic salmon (*Salmo salar*) and the brook trout (*Salvelinus fontinalis*). These two species make up the basis of the recreational fishery in Newfoundland and until recently (1991) a viable commercial salmon fishery was conducted around the island. A general decline in stocks and the economic importance of both the recreational and commercial fisheries to the province has focused attention on these species. It has been suggested that the decline of these stocks has been magnified by habitat destruction related to industrial development. Thus, habitat restoration and improvement was considered an important component of stock rehabilitation for these species.

The species assemblages of most freshwater ecosystems within Newfoundland are dominated by salmonids with an overall low number of species present (Scott and Crossman 1964). This depauperate faunal assemblage has been hypothesized to allow for a niche expansion in these systems (Gibson et al. 1993). Thus a number of habitats that would not be traditionally regarded as good anadromous Atlantic salmon habitat are important production areas in many Newfoundland systems (Ryan 1986; Hutchings 1986; O'Connell and Ash 1989; O'Connell et al. 1990; Ryan et al. 1993; Erkinaro and Gibson 1997; Dempson et al. 1996). This has led to a generalization that all habitats within Newfoundland have the potential for salmonid production. Thus areas that were naturally excluded from the most valued fishes (i.e. migrating anadromous Atlantic salmon) were viewed as under utilized habitats that supplied a potential for increasing the overall freshwater production for this species.

Under the prevailing conditions in Newfoundland, a logical habitat improvement strategy to increase the freshwater production potential for Atlantic salmon was to supply access routes through previously insurmountable barriers (water falls; braided channel mouths; debris dams; etc.) to allow the colonization of the upper reaches of the watershed. Due to the popularity of this methodology under both NIFDA and CASEC, and the suggestion that providing access to previously 'underutilized' habitat may be used to compensate for habitat loss due to development in the future, it was decided to conduct a limited evaluation of a few such projects. This report outlines the findings of two such evaluations conducted in the upper sections of the Gander River watershed. The first of these evaluations was conducted on Great Gull Brook, a tributary of the Northwest Gander River, the second was conducted in Dead Wolf Brook, a tributary of the Southwest Gander River. Both systems had formerly impassable water falls physically modified to allow for passage of anadromous Atlantic salmon to the upper reaches of their respective watersheds.

3.0 Great Gull Brook

3.1 Project Description

Great Gull Brook is the largest tributary of the Northwest Gander River (Figure 1) with almost 8700 units of available habitat (Traverse 1972). Most of this habitat (> 90%) was previously inaccessible to anadromous Atlantic salmon, during all but the highest water conditions, due to a waterfall that was located 2.5 kilometers upstream from the confluence with the Northwest Gander River (Figure 1; see Traverse (1972)). The Gander River Management Association (GRMA), under the auspices of the CASEC, conducted a remedial project during the summer of 1996 aimed at removing this migration barrier. A scientific evaluation of this remedial project was initiated during the summer of 1997 and continued for two years. Previous sampling conducted during 1993 in Great Gull Brook, for stock assessment purposes (Reddin et al., unpublished MS), was used as baseline data allowing a pre- and post-evaluation of juvenile fish populations.

3.2 Methods

Electrofishing surveys were conducted on four stations within Great Gull Brook during August of 1997 and 1998. Two of these stations (3 and 4) were located above the previous obstruction while two were located downstream (1 and 2). One of the stations sampled above the obstruction (station

3) was also sampled during 1993 for an unrelated project (Reddin et al., unpublished MS).

Salmonid population estimates were determined by using the fixed effort (successive) removal method. Each station was cordoned off with barrier nets to prevent immigration/emigration to/from the study site. Successive sweeps (runs) at each site were made using a backpack electrofisher, with a minimum of four sweeps per site. Electrofishing equipment (Smith-Root Type 12 model) and methods are described in detail in Scruton and Gibson (1995). Population estimates were calculated for the total population and for young-of-the-year Atlantic salmon using the Microfish 3.0 program developed by the U.S. Fish and Wildlife Service (Van Deventer and Platts 1989), employing a maximum likelihood (ML) estimator (Burnham formula, Van Deventer and Platts 1983).

All fish were anaesthetized, identified to species, measured for length (nearest mm) and weighed (only fish greater than 0+ in age) using a portable electronic balance (to the nearest gram). Total and young-of-the-year densities as well as salmonid length frequencies were compared between the stations and between the two post remedial sampling years and 1993, to evaluate any population and/or community changes that may have occurred as a result of the obstruction removal.

In addition to fish sampling, detailed habitat surveys were conducted within all four electrofishing stations during both sampling years. Each electrofishing site was typed according to a meso-habitat classification as outlined by Gibson et al. (1987) and was delineated to calculate area. Water depth (cm), mean column velocity ($cm \cdot sec^{-1}$; Marsh McBirney Flomate 200) and substrate characteristics (modified Wentworth scale) were collected at one meter intervals along three representative cross section transects per station. Discharges were calculated and habitat parameters compared between upper and lower stations to evaluate differences in the quantity and quality of available habitat.

3.3 Results and Discussion

Salmonid density estimates ranged from 0.05 to 0.94 fish $\cdot$ m^{-2} during 1997 and from 0.03 to 0.72 fish $\cdot$ m^{-2} during 1998 in the four sampling stations (Figure 2). Densities were much higher in the lower stations in both sampling years with the relative abundance between sites being similar for both years (Figure 2). The density observed in 1993, which would correspond to station 3, was 0.19 fish per m^{-2} (Reddin et al., unpublished MS). The 1993 density, although higher than those observed in the same area during the 1997/98 estimates, was still significantly lower than the densities observed in the lower stations. Further more the community structure in the lower stations was almost exclusively juvenile Atlantic salmon (> 99.9%) while the upper sections had a mixture of Atlantic salmon (60%) and brook trout (40%).

The length frequencies of Atlantic salmon juveniles observed in the lower stations (1 and 2) during both years had a maximum fork length of <130 mm with the dominant age-class being the young-of-the-year (approximately 40-70 mm) (Figure 3). This length frequency distribution suggests that there were three juvenile age-classes present in the lower sections and the lack of larger fish suggests an absence of landlocked individuals within this area. The positively skewed length frequency distributions might be expected in a population derived from an anadromous stock because the larger individuals would have smoltified and moved downstream before the August sampling dates. The length frequencies in the upper stations (3 and 4) were different during the two sampling years (Figure 3). Young-of-the-year fish were present in both upper stations during the first sampling year (1997) and these were composed of approximately 50% Atlantic salmon and 50% brook trout. The young-of-the-year size-class was generally absent in the upper stations during 1998. The larger fish observed in these stations were > 180 mm and were always Atlantic salmon, coupled with the sampling time (August) being well after the smolt run it is probable that these fish were derived from a landlocked population.

The reasons for the lower utilization by Atlantic salmon in the upper reaches of Great Gull Brook does not appear to be due to differences in habitat features (Table 1). The upper stations were slightly shallower with a higher mean column velocity but all observed habitat features were well within the preferred ranges for Atlantic salmon in Newfoundland (deGraaf and Bain 1986; Terrell et al. 1995; Scruton et al. 2000). Substrate distributions were different between the two areas with the upper sections having a lower percentage of gravel sized substrate, which may reduce young-of-the-year production (Clarke and Scruton 1999), but would not explain the abundance and community structure differences observed between the two areas. Sedimentation from road construction may however have played a role in reducing the habitat quality of the upper reaches. A short intense rainstorm (< 15 mins) occurred during the electrofishing surveys of this area during 1998 which resulted in a significant influx of sediment to the area.

The results of our electrofishing surveys do not rule out the possibility of anadromous Atlantic salmon being present in the upper reaches of Great Gull Brook. They do however clearly demonstrate that these upper areas are less productive for this species and have apparently not been successfully colonized to date. This lower production of Atlantic salmon may be due to a number of reasons including a low number of spawners utilizing the available habitat; an overall lower habitat quality; competition from brook trout and landlocked Atlantic salmon among others. Any of these attributes would keep the area below its carrying capacity for juvenile anadromous Atlantic salmon and therefore, the upper reaches of Great Gull Brook should not be considered on par with areas below the former obstruction for stock assessment and management purposes.

The colonization of the upper reaches of the Great Gull Brook was left to natural straying by adult Atlantic salmon, a process which is generally slow and often not successful (M. F. O'Connell DFO; pers. comm.). It is expected that this natural straying would be related to density dependant pressures to find suitable spawning areas coupled with favourable environmental conditions (i.e. good hydraulic conditions for fish passage). This trend was supported from our limited observations. There were no young-of-the-year Atlantic salmon present in the upper stations during 1998 which corresponded to the low adult returns of 1997 (O'Connell et al. 2000). Young-of-the-year were observed in these areas during 1997 and the corresponding adult returns of 1996 were the second highest recorded since the closure of the commercial fishery in 1992 (O'Connell et al. 2000). These trends suggest that the colonization of the upper reaches of the Great Gull Brook by anadromous Atlantic salmon will not occur or only occur at a very slow rate unless there is a significant increase in returning adults to the Gander River system.

4.0 Dead Wolf Brook / Southwest Gander Spawning

4.1 Project Description

Dead Wolf Brook, a tributary of the Southwest Gander River (Figure 1), was completely obstructed to upstream migration by anadromous Atlantic salmon by a series of four falls at the mouth of the river. It has been estimated that over 5000 units of habitat are available above these obstructions which could significantly add to the overall production of the Gander River system for anadromous Atlantic salmon, if it was utilized (Traverse 1972) . Thus, a habitat improvement project was initiated in 1994 which entailed blasting a series of pools and chutes in and around the upper three falls. Follow up work in 1995 included blasting a series of three pools and connecting channels around the lower falls. A concrete wall and spillway were installed to maintain depth in the lower pool. Additional remedial activities were conducted in 1996 on the upper three falls, to increase the depth in one of the plunge pools and to remove any debris that may have impeded migration. A project was conceived to evaluate fish passage at these falls in 1998 using coded transmitter radio telemetry. However, low water levels and the absence of adult Atlantic salmon in Dead Wolf Brook resulted in the project evolving and expanding to include the surveying and mapping of spawning sites within the entire Southwest Gander River using the telemetry technology.

4.2 Methods

Coded radio transmitters (Lotek model MCFT 3A) were surgically implanted in twenty four adult Atlantic salmon which ranged in size from 55 to 79 cm on August 20, 1998. Fish were collected in the mouth of the Southwest Gander River (Figure 4) by seining and/or the use of a modified Fyke net from August 15 to August 19 and held in a wire mesh enclosure until surgery could be conducted. Fish were immersed in an anesthetic bath until equilibrium was lost (3-5 minutes), aesthetic consisted of clove oil (40 ppm) dissolved in ethanol. Fish were then placed on a V-notched table for surgery. During surgery fish were kept moist at all times and fresh water was continually passed over the gills via a small portable pump. Additional anesthetic was passed over the gills at the sign of any movement during surgery, ensuring that the fish stayed under the influence of the anesthetic during handling. After surgery was complete (3-5 minutes), fish were held within the river until the effects of the anesthetic wore off, at which time the fish were released.

A fixed location remote receiver station was installed just above the last falls in Dead Wolf Brook on September 12, 1998 (Figure 4) to monitor fish passage through this area. This remote station was powered by solar panels and had the capability of continuously monitoring the area for transmitters and storing the data (i.e. data logging) on a memory chip. This monitoring station was removed and data downloaded on November 3, 1998.

A manual tracking survey, to locate fish containing radio transmitters during the spawning period, of the entire Southwest Gander River and its tributaries was also conducted on November 3, 1998. Tracking was conducted from a helicopter, affixed with a H-antenna, moving at a speed of approximately 60-70 km/hr at a altitude of less than 100 meters above the river, which was well within the transmission range of the transmitters. Once a tag was located its geographic position was recorded using a hand held GPS (model: Garmin II Plus). Landmarks were also recorded to help in mapping the locations. These locations were subsequently entered into a Geographic Information Systems (GIS) program (SPANS) and overlaid onto a map (1:50,000) of the river to delineate likely spawning areas within the system (Figure 4).

4.3 Results and Discussion

Construction crews observed successful fish passage through Dead Wolf Brook after the completion of remedial activities in 1995 and fish were observed below the falls in July 1996 but had either moved upstream or had returned downstream by August 1996. The remote telemetry station did not record any successful passages from September 12 to November 3, 1998 and no fish were located in the tributary during the manual tracking (Figure 4). It should be noted that the low numbers of tagged fish that were released into the entire Southwest Gander River reduced our ability to confidently evaluate fish passage in Dead Wolf Brook. The original study plan was intended to collect all fish downstream of the falls on Dead Wolf Brook therefore increasing the likelihood these fish would attempt to surmount the falls. However, this plan could not be implemented as low water conditions kept fish from entering the Southwest Gander System until late summer/early fall 1998.

A total of 14 tagged salmon were located during the manual tracking on November 3 (Figure 4). Twelve of these fish were located in the main stem of the river, following from the mouth through to Little Gander Pond, with two of the fish being located in the tributary east of Little Gander Pond (Figure 4). Ten fish were located in the upper part of the watershed, while three were located in the lower part of the main stem, and one fish was located in the middle section of the river. Any area with more than one fish located during this survey was considered to be a major spawning area. The most important spawning area within the system, based on our limited sample, appears to be the immediate downstream area of Little Gander Pond where 5 of our tagged fish were located. Three fish were located in the lower main stem with aggregations of two fish at the branch leading to Little Gander River and east tributary from Little Gander Pond (Figure 4).

5.0 Summary

The two obstruction removal projects within the Gander River watershed, Great Gull Brook and Dead Wolf Brook, have not demonstrated immediate colonization of the newly accessible habitats by anadromous Atlantic salmon. This finding is not surprising given the short time period that has passed since the habitat alterations were completed and the prevailing environmental conditions over that period. There has been some indication that areas above the falls in Great Gull Brook have been utilized by Atlantic salmon in years having a strong adult spawner return to the entire Gander River system coupled with favorable hydrologic conditions (i.e. medium to high water years). However, it is impossible to conclusively ascertain if juveniles observed in the upper reaches were the progeny of anadromous or landlocked fish or a combination of both.

Biological and hydrological considerations are important to the success of habitat enhancement projects (Scruton et al. 1997). The biological considerations include a knowledge of the target species, an understanding of the limiting habitat factors, microhabitat preferences of species in their natural habitats, intra- and inter-specific interactions, seasonal and life-stage specific habitat requirements, availability of food, and others. Habitat levels do not appear to be a limiting factor in the Gander River system at the present level of adult spawners. This being the case, the colonization of new habitats through natural straying and the resulting increase in overall production may take a much longer time span than has passed in these examples. This process will be further slowed due to natural population fluctuations unrelated to freshwater habitat conditions (e.g. sea survival rates) such as those observed during 1997 (O'Connell et al. 2000).

6.0 Conclusions and Recommendations

The telemetry results, although not providing any concrete evidence of adult salmon passage into Dead Wolf Brook, have supplied very valuable information on spawning areas within the entire Southwest River. This information may play a vital role in future habitat management decisions such as forestry allocations, access road placement and future cottage developments among others. Spawning areas should be accorded extra protection during any developments within the watershed. We recommend that the spawning areas highlighted in our survey, especially the downstream area of Little Gander Pond, be considered critical habitats for Atlantic salmon production within this watershed. The use of radio telemetry, in the Dead Wolf example, also highlighted the power of this methodology to elucidate habitat utilization patterns on a temporal scale within a large watershed. A similar study design may benefit studies aimed at identifying critical habitats for use in habitat and/or resource management plans. Recognizing that the telemetry study only included a sample of 24 fish, it is recommended that a more detailed telemetry based assessment of 'critical' habitats be conducted in the Gander River system, to confirm the results of 1998 and to further identify other important spawning areas. Additionally, owing to the longevity of newer transmitters, it is recommended that a similar survey be conducted in winter to determine over wintering locations. These locations may be critical in the survival of post-spawned adult salmon and hence play an important role in the overall production of the population as a whole.

The effects on the natural populations should be considered before any plans to open habitat for the use of another species are finalized. This is especially important in Newfoundland were both the existing populations and the target species for enhancement are generally salmonids. The habitat utilization patterns for many of our salmonid species have expanded from their norms to include most niches within the ecosystem (Gibson et al. 1993; Clarke et al. 1997). Thus it follows that an introduction of a new species which will be more competitive in some of these habitats will adversely affect the production of the existing populations (Cunjak and Green 1983). For example, it could be expected that the juveniles of anadromous and landlocked Atlantic salmon would have similar habitat requirements and any increase in the anadromous component may be at the expense of the existing landlocked component, especially if the habitat is already at its carrying capacity. Furthermore, our understanding of the competitive interactions of species in insular Newfoundland is poor, particularly in consideration of niche expansion.

The methodology of opening migration routes to new habitat in isolation of any other enhancement practices does not appear to provide a reasonable expectation for increasing productive capacity. The process of colonization would be expected to be erratic and subject to density dependent factors which would require decades to realize an equilibrium. Furthermore, our incomplete understanding of the competitive interactions for many species assemblages would subject the process to even more uncertainty. If, after the consideration of other methods for compensation, the opening of new habitats is required to offset the harmful effects of a development project, then adult transfers and/or eggs/fry transfers may be the only means to speed up the colonization process (see O'Connell and Bourgeois 1987). In addition to these transfers a detailed monitoring program to include both the target species and the natural populations within the newly opened habitats would be recommended.

During the electrofishing studies, sedimentation from the road crossing on Great Gull Brook was determined to be a major concern as it would be expected to reduce salmonid production and deter fish from entering these areas. An evaluation of the area around the road crossing should be undertaken and if a substantial and chronic sedimentation problem does indeed occur remedial activities should be considered to rectify the problem. Furthermore, this problem may be more widespread and may be posing a constraint on production throughout the island's network of resource roads. Work on an inventory of road crossings is ongoing within the island but more effort needs to be placed on developing and testing methodologies to reduce sedimentation from these areas.

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Table 1: Habitat features of the Great Gull Brook electrofishing stations.

Station	Length (m)	Width (m)	Area (m^2)	Mean Depth(cm)	Mean Velocity (cm/s)	Habitat Type	Substrate Distributions % Bedrock	Boulder	Cobble	Gravel	Sand
1	20	16.8	336	13.27	10.31	Flat	-	18.9	51.6	27.5	2
2	20	19.3	386	11.8	7.25	Flat	-	25.3	40	32.5	2.2
3	20	15.9	318	9.29	12.24	Flat	2	19.8	66.5	11.6	-
4	20	16.6	332	9	12.37	Flat	5.8	32.5	52.5	7.5	1.7

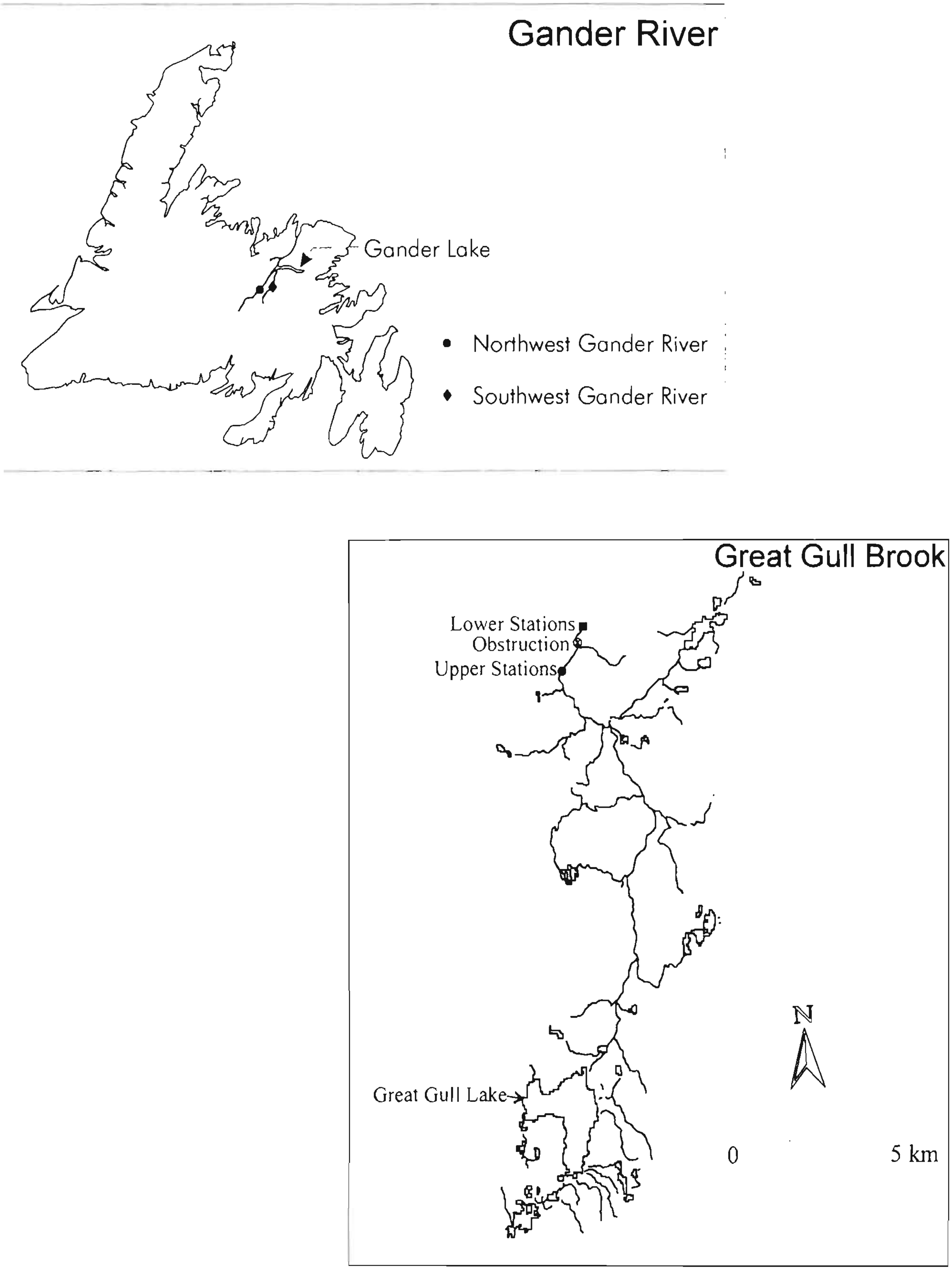

Figure 1: Top panel depicts the location of Northwest and Southwest Gander Rivers within the Gander River system. The lower panel shows Great Gull Brook, a tributary of Northwest Gander River with sampling sites highlighted.

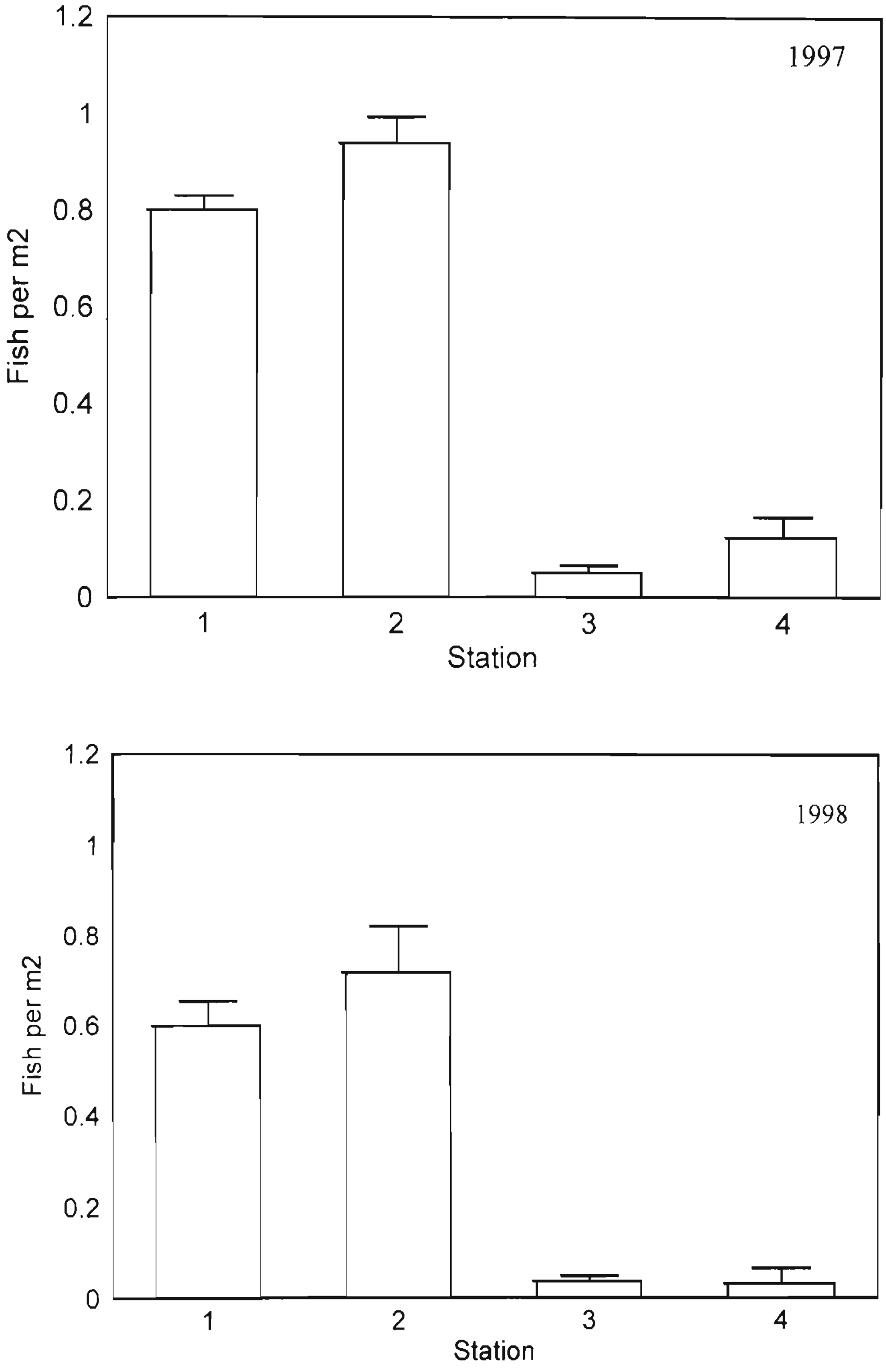

Figure 2: Salmonid densities (fish per m^2) in sampling stations in Great Gull Brook during 1997 and 1998. Station 1 and 2 were downstream of obstruction; stations 3 and 4 were upstream.

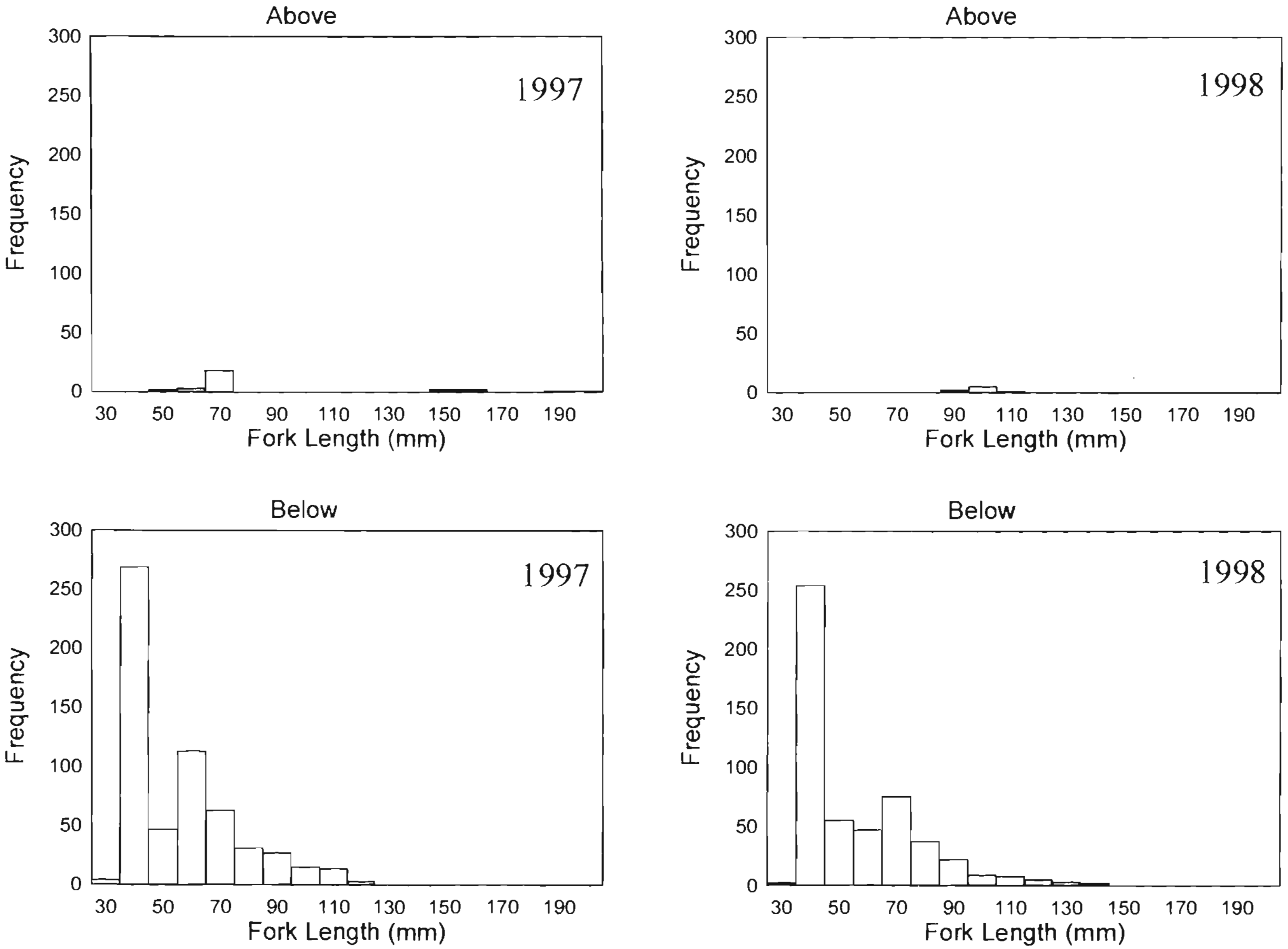

Figure 3: Size distributions of Atlantic salmon captured above and below the obstruction in Great Gull Brook. Data for stations 1 and 2 (below) and 3 and 4 (above) have been combined.

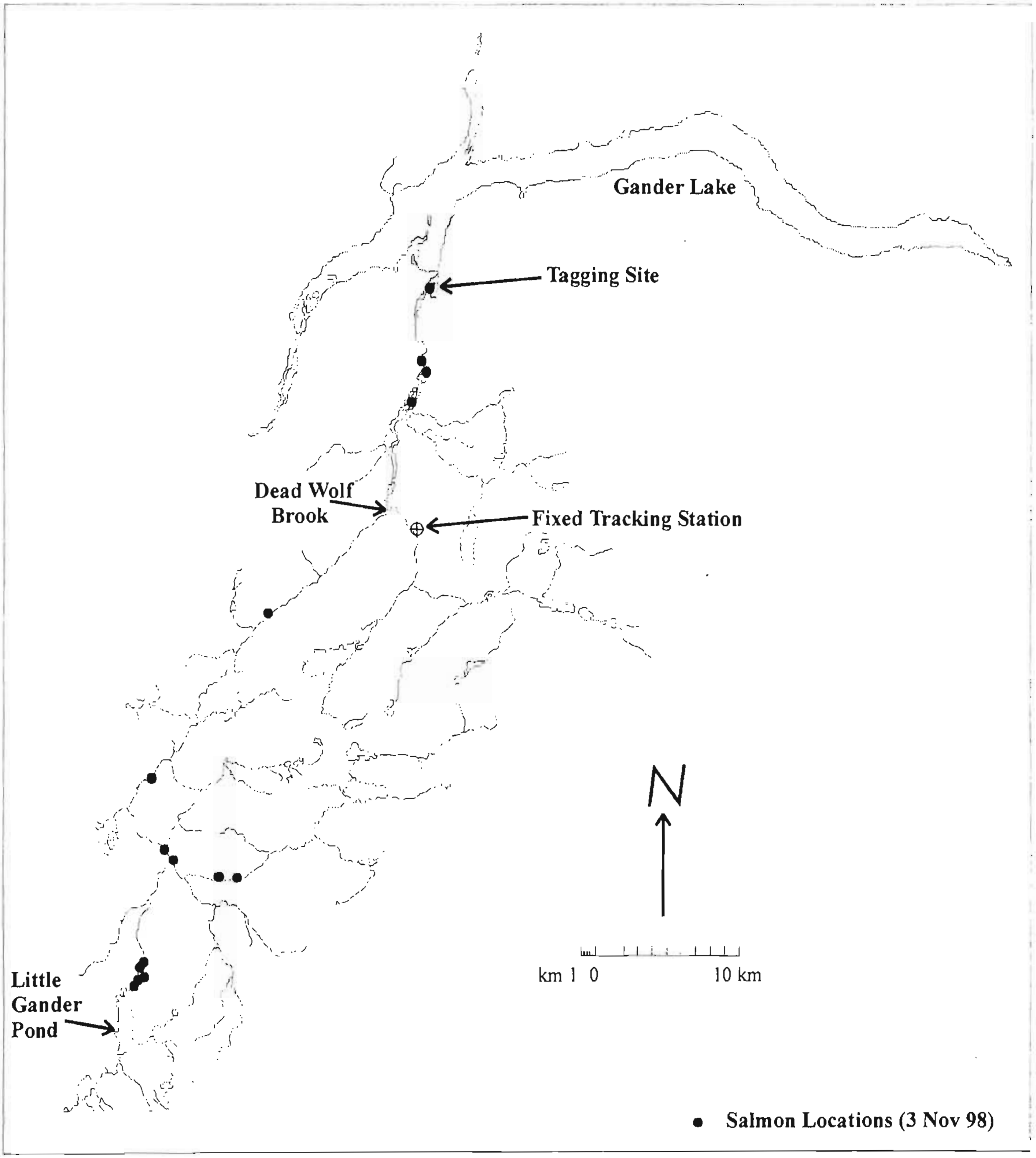

Figure 4: Location of adult salmon, and likely spawning locations, within the Southwest Gander River on November 3, 1998.